DEC 1 1972

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In 1660, 281 years ago, in an essay on the usefulness of natural history, Robert Boyle, the English philosopher and scientist, who, in addition to his contributions to physics, studied the chemistry of combustion and respiration, wrote these prophetic words - "He, that thoroughly understands the nature of ferments and fermentations, shall probably be much better able than he, that ignores them, to give a fair account of divers phaenomena of several diseases (as well fevers as others) which will perhaps be never thoroughly understood, without an insight into the doctrine of fermentations." Almost two centuries elapsed before Boyle's prophecy was fulfilled and its implications realized by the studies of Pasteur (1857) on microbial fermentation. With all the important work Boyle accomplished in physics his name is associated especially with ~~foundation~~ of chemistry as a separate science. He was primarily a chemist; so too was Pasteur. Furthermore, both men had adopted a physiological attitude of mind in their experimental work. Indeed, Boyle is said actually to have carried out experiments on physiology - a field, however, in which his biographers tell us he was hampered by "the tenderness of his nature" and his consequent dislike of anatomical dissection. Pasteur, a chemist by training, realized full well the physiological implications of his studies in fermentation and constantly insisted that the chemical activities of microorganisms were but the expression of physiological processes adapted to promote some vital need or purpose. It was

through no fortuitous circumstance or mere accident then, that microbiology from its very inception became intimately linked with chemistry, physiology and medicine

As Boyle foresaw, it was the insight into the nature of fermentation that enabled Pasteur to give a fair account of several diseases; that such diverse diseases as those of silkworms, chicken cholera and rabies in man and animals are due to living infectious agents as specific in behavior as the microbial agents of fermentation are selective in the type of chemical change they induce.

It is not my purpose to review the historical developments of bacteriology or the rapid succession of discoveries that followed the announcement of the doctrine of fermentation and the germ theory of disease - with these you are all familiar. Nor shall I dwell upon the brilliant achievements of ~~the~~ these pioneers ~~of~~ in bacteriology whose explorations in the field of infection and immunity ~~have~~ disclosed the basic principles that underlie modern advances in the medical, agricultural and soil sciences. But I cannot refrain from reiterating and again emphasizing the interdependence and common interests of these specialized fields; the reciprocal benefits and mutual enrichments that have accrued from ~~that~~ the early and increasingly fruitful union of microbiology with chemistry, physiology and medicine.

(The moral is not far to seek - and its application to our own Society is perhaps not too remote"). Our membership, constantly growing in numbers, comprises groups of individuals highly specialized and primarily interested in one or another of the several fields of bacteriology . There is a natural preoccupation with the subject matter of one's own field; a tendency, perhaps less justified, to regard his own corner of knowledge as the source and direction of all biological thought. Now I am not indicting the microbiologists alone and certainly not any particular group within our organization. In proof of the fact that such tendencise are common to all sciences may I recall the words of the president of one of the great foundations which distributes funds for scientific research - "Choose off the shelves a group of learned treatises and sample the prefaces : Mathematics:- it is the queen of sciences; Physics: - it is the source of the basic laws for the behavior of all matter; Chemistry;- a recent text says, 'Chemistry touches all human interests. It is the central science; Biology:- it assaults the greatest mystery of all, the mystery of life; Astronomy:- it has the cosmos and eternity for its heroic theme; Philosophy :- - it is an examination of the ultimate questions which give life meaning " And so one could expand the list, with brave and startling claims for the central character and basic importance of one field, one speciality, one segment of knowledge after another" page 32.

It is perhaps just as well that there was no copy of a learned treatise on

microbiology on his book shelf or he might have added; Microbiology: - it assaults the greatest mystery of all, ~~the mystery of life, of the smallest of living things~~. He graciously says in explanation of these seemingly contradictory and exaggerated claims that "they arise partly because of the egocentric character of man, but they are also due to wholly selfless enthusiasms, to the concentration to which specialized competence naturally leads."

"C" By way of illustration, may I cite one or two ~~of the many~~ examples of the many ways in which microorganisms serve as highly sensitive reagents for unravelling many important biochemical problems in bacterial, ~~nutritional~~ and animal physiology and nutrition.

Knowledge of specific and exacting requirments of various species of microorganisms for vitamines, many of which ~~and biocatalysts, which~~ form the prothetic groups of vital enzyme systems, has lead to development of biological methods of increasing precision for determination of ~~the presence of~~ these essential substances in animal blood and tissues. The ~~achievement establishing~~ establishment of the complete identity of biotin, coenzyme R, and vitamin H was greatly facilitated when instead of the laborious, time consuming and espensive method of rat assay, Kögl found that this chemical entity could be more readily and accurately determined by microbiological tests with rhizobium and yeast cells. The identification and isolation from egg albumin of ~~the~~ a substance, avidin, which is responsible for the so called egg white injury of animals, was likewise greatly aided by the use of microbiological techniques. For history & chemical [illegible] →

(A) insert in middle of page 4.

The moral is not far to seek but its application in our faculty is perhaps not too simple. Despite many eccentric natures, despite the wholly sheepish enthusiasm for the concentration natural to specialized competence in any one field of bacteriology, let us never lose sight of the fact, that the solidarity of this Society rests upon "the unity of its intellectual life and this life cannot, without disaster, be broken up into separate spheres". (Start here new paragraph beginning top page 5)

(insert ¶ A study of the behavior etc — (top of page 5) marked B.

Continuation of text on line page 4

→ incident to the isolation of avidin its presence in any given fraction could be quantitatively followed by observing the absence of bacterial growth in culture media to which the suspected materials had been added; since avidin by combining with & rendering unavailable the free biotin in the medium deprives the bacterial cells of this essential metabolite and thus prevents their growth.

Follow here ¶ D. page 5.

~~the use of microbiological techniques.~~

Study of the behavior of microorganisms has greatly aided in the formulation of ~~the~~ principles that have given new thought and direction to biochemical investigation. Analyses of certain processes involved in the metabolism of unicellular microorganisms have materially helped in the elucidation of many ~~of the~~ problems relating to animal and plant physiology, and have added to the understanding of the part biocatalysts have in the chemical events and transformations in living tissue cells. Thus, from these fields there is ~~now~~ accumulating a significant and integrated body of facts which together constitute what is referred to as "comparative biochemistry". This is further evidence of the growing recognition of the similarity, even perhaps the unity of many of the principles that govern the cellular functions and chemical activities of diverse living things, from the lowest to the highest forms, from the miraculous microbe to man himself.

The isolation from soil bacilli of enzymes capable of specifically attacking creatinine has provided biologically specific techniques that have proved useful in the study of human metabolism. Much of the knowledge concerning the intermediate metabolism of carbohydrate in man has been derived from study of similar enzyme systems in yeast cells. With all due reverence for the sanctity of Holy Script I think I may still possess the intent of that proverb of Soloman in which he councils the sluggard to learn diligence by observing the ant, when I say to you microbiologists, to the physiologists and biochemists

as well. "Go to the microbe, thou scientist, consider its ways and be wise."

During the latter half of the 19th century, it was established that plants utilize CO_2 for the synthesis of their cell materials, finding the energy required in photochemical reactions catalyzed by chlorophyl. Animal cells, on the other hand, were known to require complex organic carbon for the building up of their protoplasm, as well as for all their other biochemical reactions. Toward the end of the last century (1887) it was shown that, like plants, certain bacteria (the autotrophic group) can utilize carbon dioxide for their synthetic processes finding their energy in the oxidation of simple inorganic compounds. On the contrary, like animal cells, heterotrophic bacteria were believed to utilize only organic carbon. Within the past 6 years, however, it has been recognized that certain heterotrophic bacteria can incorporate carbon dioxide into more complex organic compounds; for example, forming succinic acid during the fermentation of glycerol in the presence of carbon dioxide. Furthermore, it has only recently been found that the animal organism has to a limited but definite degree the power to synthesize organic compounds from CO_2 - a power long supposed to be a peculiar prerogative of chlorophyl bearing plants. Investigators have injected bicarbonate containing radio active C into animals and from their livers have recovered glycogen containing the isotope carbon. Moreover it has also been shown "in vitro" that, by the use of isotope C, liver tissue from pigeons can cause CO_2 to enter into organic combination to form

ketoglutaric acid and amino acids. The first recognition of the utilization of carbon dioxide by heterotrophic bacteria, and the recent subsequent finding of the participation of CO_2 in the carbohydrate cycle in animals indicates that the phenomenon is probably of universal occurrence. When taken together these interlocking facts constitute a new and striking example of the biochemical unity of life.

Therefore I say again: – Go to microbes, thou scientist, consider their ways, and be wise –

The strategy of warfare against infectious agents of disease lies not alone in discovery of ways and means of fortifying the natural and specific defenses of the host, – important as these are, but in a concerted effort on the part of microbiologists to learn the vulnerable points of attack in the structural and cellular mechanisms by which these hostile agents invade and overcome the living tissues of man, animals and plants. The importance of the normal and immune reactions of the host I value not less in emphasizin more on this occasion, the significance of gaining deeper insight into the mode of life, the aggression weapons and predatory ways of the microbial invader whip of pathogenic agents. In the light of present knowledge and (faith in vision of the 17 century scientist,) I venture to add to the prediction of the seventeenth century scientist from a modern standpoint that he who understands the nature of the host-parasite relationship shall probably be much better able than heretofore [illegible] be able to give a more adequate account of the pathogenesis diverse phenomena epidemiology and control of the infectious diseases which still [illegible] problems that still baffles medical science.

[illegible] the comparative biochemistry of the host & parasite. Herein lies the intellectual challenge to students of

In a recent report by of the R. F. from which I ~~shall~~ quote ~~freely~~, Mr. Raymond B. Fosdick in speaking of "Science and the Moral Order" expresses in fine weighted words the spirit of man's search for truth:

"In spite of the claims and accomplishments ~~"Dr. Fosdick says"~~ Science is today under sharp attack. The growing public realization that its powerful tools can be used for man's enslavement and destruction has given rise to bitter questions and charges; and we ~~that~~ hear today of civilization betrayed by science and of a degraded science that shirks the spiritual issues and hypnotizes its victims with its millions of gadgets)

"In this hour of intellectual confusion and moral chaos the social consequences of science, he continues, have been brought to the fore and the question is persistently asked: Are these consequences so important, because of technical applications, that the social interest is paramount over intellectual interest? Are there too many nations and too many people everywhere using the instruments of a civilization they have not yet achieved? Are bigger telescopes and cyclotrons(more powerful electron microscopes and ultracentrifuges) needed in a world like this?"

"The question arises, Mr Fosdick points out, because science as a technique for gaining understanding of nature is also a technique for gaining control over nature - that is, it is a technique for gaining power," ~~and power~~

canbe used by evil men to do evil even more obviously and dramatically than it can be used by men of good will to do good"

"But this, he points out, is true of many things in life - The sulphonamides one of the most beneficient developments of modern medical science came from the German dye industrys, but so did mustard gas:- and he might have added the Mendelian principles of heredity came from the monastery, but so did gun powder. As he remarks "Exactly the same principles of physics are employed to point a 500 ton telescope at a star and a 15 inch naval gun at its target. Language too is a powerful tool which can be used to mirror spiritual insight or to spread false and destructive propaganda. The possibility of misuse is not an argument for no use at all." The charges that scientists disavow concern with social consequences arises from the narrow view of science. "For science" as he says "is more than the technologies that cluster about it - more than its inventions and gadgets. It is even more than the discovery and correlation of new facts. "Science," said he, "is method, a confidence and a faith. It is a method of controlled and rechecked observations and experiments, objectively recorded with absolute honesty. It is a confidence that truth is discoverable. It is a faith that truth is worth discovering."

I am not here concerned with the philosophical arguments of whether pure science is or is not necessarily a moral force. Happily microbiology needs no defense

of its intellectual aims or its social ends. They have never been accused of irresponsible indifference to social consequences. They have undeniably and always been in the service of human welfare.

But I am now concerned with our moral obligations; In this hour of national peril when our own country - so swiftly and treacherously attacked - has been forced into the most cruel and infamous war in history, we individually have loyally pledged our services in defense of country, liberty and civilization. This is our duty, which each will discharge to the limit of his ability and strength, a national obligation. In these days when the threat of an intellectual black-out abroad has already darkened laboratories and universities hitherto beacons of knowledge, when by the mad spirit of conquest, scientists in vanquished countries have been exiled and scholarship enslaved by political ideology, we, as members of this scientific organization have another duty - an obligation to international science: We need be gravely concerned about the future of science and its share in the world order that is yet to be.

Only 3 months ago a group of distinguished scientists, several from overseas, met in war distracted London to consider the international relations of science and its part in world planning after the war.

~~Science is Mobilized for War (Sir William Bragg, Overseas Journal of the B.B.C. #67, Jan. 12-18, 1941~~